

QCD and Collider Physics — Update

0 Preface

Add ‘Preface to the second edition’, describe reasons for new edition:

1. subject moves on after 8 years
2. new theoretical results (e.g. even higher order corrections, improvements in resummation etc.)
3. shift of emphasis in experiment: from LEP/HERA/Tevatron to LHC/LC/NuFac; QCD still an essential component of Standard Model at these machines
4. update of parameters
5. correction of mistakes

1 Fundamentals of QCD

1.1 Colour SU(3)

Update Table 1.1; new version of Fig. 1.2 and update PDG reference.

1.2 Lagrangian of QCD

1.3 Local gauge invariance

1.4 Feynman rules

1.5 Choice of gauge

1.6 Exact symmetries

1.7 Approximate symmetries

2 Asymptotic freedom and confinement

2.1 The running coupling constant

2.2 The β function

In this and following sections, update β -function, Λ treatment and accompanying text to put more emphasis on NNLO results and phenomenology, rather than just NLO as at present.

2.3 Asymptotic freedom

2.4 Quark masses

2.5 The Λ parameter

Update values in (2.61,2.62) and surrounding text, and Fig. 2.5.

2.6 Lattice QCD

Update Figs. 2.7, 2.8, 2.9?

3 QCD in electron-positron annihilation

3.1 The total hadronic cross section

Update measured R value in text.

3.2 Heavy quark production

Are any more of the HO corrections known now?

3.3 Jet cross sections

Fig. 3.6: update to include LEP2 data.

Fig. 3.7: check it is still the ‘best’ LEP1 figure.

Discuss current status calculation of jet rates at NLO/NNLO (3 jets at NNLO, 4 jets at NLO); maybe also show data on 4-jet rates vs NLO prediction.

3.4 Event shape variables

Include new discussion and plot(s) on power corrections to jet rates and event shapes, probably as new subsection, called ‘Power corrections to jet rates and event shapes’.

3.5 The triple-gluon vertex

Might be good to include the famous two-dimensional plot of colour factors measured from fits to four-jet events, to ‘prove’ SU(3); but why didn’t we include this before?

3.6 Gluon emission from heavy quarks

3.7 Summary and outlook

Rewrite this to mention more explicitly the Linear Collider.

Also, we don’t really do justice to $\gamma\gamma$ physics which will be important at LC; in particular, tests of BFKL in $\gamma^*\gamma^* \rightarrow$ hadrons at high energy (but how to do BFKL before Chapter 4?)

4 Deep inelastic scattering

4.1 Deep inelastic scattering and the parton model

Update Fig. 4.2 with more recent HERA data.

Update Fig. 4.3 with more modern MRST pdfs (at leading order instead of NLO?).

4.2 The parton model from field theory

4.3 The parton model and QCD

Now mention the NNLO formalism explicitly, perhaps even add NNLO curves to Fig. 4.9 if available.

Update Fig. 4.10 e.g. with HERA data included.

Update Figs. 4.11 - 4.13, or even omit these if space is tight.

4.4 QCD fits to deep inelastic data

Rewrite this section, update Λ values, discussion on higher-twist etc.

Include a new figure showing coverage of all DIS experiments in (x, Q^2) space?

Also mention limitations of QCD fits (small x , small Q^2) and discuss quality of fits for $LO \rightarrow NLO \rightarrow NNLO$.

4.5 Sum rules

4.6 Deep inelastic scattering at small x

This probably needs a major rewrite. De-emphasise BFKL? Since now accepted that ‘pure BFKL’ is not appropriate for structure function phenomenology.

Likewise for parton saturation.

4.7 Polarized Scattering

Update Fig. 4.26.

Also, add more formalism to cover the case of polarised DIS at a neutrino factory (i.e. many more structure functions involved).

5 Parton branching and jet simulation

5.1 Parton branching

5.2 Evolution equations

5.3 Monte Carlo method

5.4 Backward evolution

5.5 Coherent branching

5.6 Hadronization models

5.7 QCD event generators

6 Jet properties beyond fixed order

6.1 Jet fragmentation

6.2 Generating function method

6.3 Multiplicity distributions

6.4 Quark and gluon jet differences

6.5 Resummation of event shapes

6.6 Resummation of jet rates

6.7 Average jet multiplicity

7 Hadroproduction of jets and photons

7.1 The QCD improved parton model

7.2 Factorization of the cross section

7.3 Luminosities

7.4 Kinematics and jet definition

7.5 Two-jet cross sections

7.6 Comparison with experiment

7.7 Multijet production

7.8 Jet profiles

7.9 Direct photon production

8 Electroweak interactions

8.1 Gauge boson interactions

8.2 The Higgs mechanism

8.3 Fermion multiplets and interactions

8.4 W and Z decay properties

8.5 Vector boson scattering

8.6 Vector boson pair production

9 The production of vector bosons

9.1 The Drell-Yan mechanism

9.2 Perturbative QCD corrections

The NNLO corrections to $d^2\sigma/dMdy$ are now known (Anastasiou et al.) and should be mentioned at end of section and maybe even plotted.

9.3 Comparison with experiment

Could update Fig. 9.4 although it would hardly change.

There must now be an update of Fig. 9.5 with better statistics at high mass.

9.4 W and Z boson production

Check SM values of W and Z width and branching ratios quoted in text, also rewrite this to describe/show final Run 1 data used to measure the W width.

In figures like Fig. 9.7, do we want to keep 1.8 TeV or replot for 1.96 or 2 TeV?

Can presumably get a much better version of Fig. 9.8 (lepton asymmetry).

Is it worth showing Fig. 9.9 still? We learn nothing from it.

Update mass measurements and discussion.

Update p_T distribution figures (Fig. 9.11, 9.12); also could broaden discussion to say more about matching of resummed and fixed order calculations.

For $\sigma(W + \text{jets})$, now discuss NLO corrections where known; maybe an extra figure to Fig. 9.13 to show a ‘precision’ comparison to $W + 1 \text{ jet}$ data?

10 Heavy quarks

10.1 Charm and bottom quark decays

10.2 Top quark decays

10.3 Heavy quark production

10.4 Charm and bottom quark production

10.5 Top quark production

10.6 Heavy quarks in jets

10.7 Quarkonium

11 Higgs bosons at high-energy colliders

This chapter needs careful rewriting so that it includes the very latest on Higgs phenomenology pre-LHC.

11.1 Higgs mass constraints

Obviously update this to show the famous χ^2 versus M_H plot from precision electroweak fits; statements made at end of section are now hopelessly out of date!

Also, if we believe the $M_H < \sim 200$ GeV upper limit, then many of subsequent (BR, width, etc) plots are irrelevant!

11.2 Decay channels and branching ratios

Check the details to see whether new parameters, K-factors etc. should be used to make the plots in Fig. 11.1.

11.3 Higgs search at LEP2

Complete rewrite; really just to advertise lower limit. Or, better, just absorb this section into the ‘mass limits’ discussion of 12.1.

11.4 Higgs production at the LHC

Most of this is still probably OK, although the plots should be updated with known K-factors, more recent pdfs etc.

Fig. 11.8 now probably irrelevant since m_t now accurately known.

11.5 Search strategies and backgrounds

Complete rewrite to make it up to date. Get help from ATLAS and CMS.

11.6 Summary

We must include something about Higgs at LC for completeness; even just a sample plot or two, or a new section ‘Higgs production at a Linear Collider’.

Also, our only mention of MSSM is a long paragraph at end of this chapter!

Do we need a new chapter/section on SUSY phenomenology at LHC, including e.g. SUSY-Higgs, squark and gluino production etc etc?

12 Measurements of the strong coupling constant

Update all these numbers obviously, but the section headings still look OK.

12.1 Summary of α_S measurements

12.2 Deep inelastic scattering

12.3 τ lepton decay

12.4 Quarkonium

12.5 e^+e^- annihilation

12.6 Hadron-hadron scattering

12.7 Conclusions